Trends in Post-Concussive Symptom Reporting Following Mild Traumatic Brain Injury in Operation Iraqi Freedom

LCDR Andrew J. MacGregor, PhD MPH, Amber L. Dougherty, MPH,

Janet J. Tang, MPH & Michael R. Galarneau, MS

Department of Medical Modeling, Simulation, and Mission Support
Naval Health Research Center
140 Sylvester Road, San Diego, CA 92106
Phone: 619-553-7026, Fax: 619-553-8378

andrew.macgregor@med.navy.mil

ABSTRACT

Background: *Post-concussive syndrome (PCS), which includes physical, neurological and cognitive complaints, frequently occurs following mild traumatic brain injury (TBI). Research in civilian populations has demonstrated PCS symptom recovery over the course of one-year post-injury, with a majority of symptoms resolving within the first 90 days. The recent military conflicts in Iraq and Afghanistan have resulted in an increased prevalence of TBI, in large part due to a preponderance of blast-related weaponry. Little is known regarding the course of PCS symptoms following combat-related TBI, and whether it differs from other concussion mechanisms seen in civilian populations (e.g., sports-related). Complicating matters is the overlap of symptoms between TBI and post-traumatic stress disorder (PTSD).*

Methods: *The Expeditionary Medical Encounter Database (EMED) allows for the unique assessment of symptoms following mild TBI. The EMED contains clinical records completed in-theatre, which includes exact dates of injury. This addresses limitations of recent research of combat-related TBI, which relies on self-reported information with no knowledge of when the actual event occurred, thus making it impossible to document trends or changes in post-concussive symptoms over time. A non-head injured control group was utilized for comparison purposes. The EMED data was linked with post-deployment health assessment (PDHA) data. The PDHA is given to personnel at the conclusion of their deployment. Because a TBI event can occur at any time during a deployment, personnel can answer a PDHA anywhere from days, weeks to many months after injury. For this analysis, personnel were categorized into those responding to a PDHA within 1-90 days (n = 386 TBI, 1332 non-head), 91-180 days (n = 382 TBI, 1074 non-head), and 181-365 days (n = 88 TBI, 378 non-head) from the time of injury. Common PCS symptom complaints on the PDHA were examined and included pain (headache, back, joint, muscle), memory problems, sleep problems, and tinnitus. The PDHA also contains a screening instrument for PTSD, which was adjusted for in all multivariate analyses along with age, injury severity, combat exposure, and blast mechanism.*

Results: *Multivariate analysis yielded differing PCS symptoms for each of the PDHA response periods. In the 1-90 day post-injury period, those with TBI had significantly higher odds of headache (OR 4.81, p-value < 0.001), back pain (OR 1.82, p-value < 0.001), and memory problems (OR 2.74, p-value < 0.001) compared to non-head injuries. In the 91-180 day period, only headache was significantly higher (OR 2.15, p-value < 0.001) in TBI. Finally, in the 181-365 day period, there were higher odds of headache complaints (OR 2.32, p-value = 0.04) in TBI compared to non-head injuries, as well as memory problems (OR 2.76, p-value = 0.02), back pain (OR 2.68, p-value = 0.003), and sleep complaints (OR 2.22, p-value = 0.04).*

Conclusions: *These findings suggest PCS symptoms change over the course of one-year following combat-related TBI. These symptoms, particularly in the early stages following TBI, may affect operational*

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
APR 2011	**N/A**	**-**

4. TITLE AND SUBTITLE
Trends in Post-Concussive Symptom Reporting Following Mild Traumatic Brain Injury in Operation Iraqi Freedom

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Medical Modeling, Simulation, and Mission Support Naval Health Research Center 140 Sylvester Road, San Diego, CA 92106

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA578905. Mental Health and Well-Being across the Military Spectrum (Bien-être et santé mentale dans le milieu militaire). RTO-MP-HFM-205

14. ABSTRACT
Background: Post-concussive syndrome (PCS), which includes physical, neurological and cognitive complaints, frequently occurs following mild traumatic brain injury (TBI). Research in civilian populations has demonstrated PCS symptom recovery over the course of one-year post-injury, with a majority of symptoms resolving within the first 90 days. The recent military conflicts in Iraq and Afghanistan have resulted in an increased prevalence of TBI, in large part due to a preponderance of blast-related weaponry. Little is known regarding the course of PCS symptoms following combat-related TBI, and whether it differs from other concussion mechanisms seen in civilian populations (e.g., sports-related). Complicating matters is the overlap of symptoms between TBI and post-traumatic stress disorder (PTSD).

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**12**	

performance. The association between TBI and PCS symptoms 181-365 days post-injury may be a result of repeated blast exposure or impeded recovery due to continued presence in a stressful environment, and warrants further study with a larger sample size.

1.0 BACKGROUND AND INTRODUCTION

Mild traumatic brain injury (TBI), or concussion, is an emerging health concern among veterans of the current conflicts in Iraq and Afghanistan.[1-4] This is due, in part, to asymmetrical warfare techniques such as improvised explosive devices and other crude forms of blast weaponry. In the current wartime environment, blast injuries account for approximately 70% of injuries among U.S. military personnel.[1] Both primary and secondary effects of these blasts are associated with TBI.[4] Further, because of enhancements in body armor and field medical care, more personnel than ever are surviving their wounds.[5] This has shifted focus to adverse, post-injury sequelae. In TBI, post-injury symptoms are often referred to as post-concussion syndrome (PCS).[6-8] Common PCS symptoms include headache, tinnitus, sleep problems, chronic pain and cognitive deficits.[8]

In 2004, the World Health Organization (WHO) performed an extensive review of the natural history of TBI.[9] They reviewed 66 studies among adult populations and found that common PCS symptoms mostly resolved on their own within the first three months post-TBI.[9] Recent reviews by McCrea et al. have corroborated the findings from the WHO report, even suggesting that only 3% of persons sustaining a TBI report symptoms beyond one month of injury.[10,11] All of these studies, however, were among civilian populations and did not examine blast injuries. The nature of blast injuries, combined with the environment in which the injury is sustained and inherent differences between military and civilian populations, may result in a different epidemiological presentation of PCS symptoms.

Regarding persistent PCS symptoms, it has been suggested that conditions other than the organic injury such as concomitant mental health conditions, may play a prominent role.[10,11] With military personnel sustaining these injuries in an austere, stressful combat environment, there is potential for co-occurring mental health disorders, particularly post-traumatic stress disorder (PTSD).[12,13] The role of these combat-related mental health disorders in the natural history of TBI has been the subject of recent research. Hoge et al. found that only headache was significantly higher among combat veterans with TBI compared to those with other injuries after adjusting for PTSD and depression.[14] Further, Pietrzak, et al. extended Hoge's findings to examine general health ratings and psychosocial functioning after mild TBI and identified a strong mediating effect of PTSD.[15] These studies are limited, however, by the use of self-reported screening instruments to retrospectively identify personnel with TBI.[16] Relying on patient recall can be problematic because TBI is known to adversely affect memory.[17] In addition, their studies do not account for the date of injury, thus fluctuations in symptom reporting as a function of time since TBI were not assessed. Finally, the screening instrument in part classifies TBI as an experience or event (e.g. blast) that left the person feeling 'dazed and confused'. This symptom is not specific to TBI, but can also occur as a natural reaction to the stress of combat.[18]

The aim of the present study was to examine the natural history of PCS symptoms among military personnel with TBI while accounting for co-occurring PTSD. The unique nature of our study population and the use of provider diagnosed injury from clinical records completed at or near the point of injury allowed for an assessment of PCS symptom reporting at various points in time post-injury. This will have implications in both predicting symptom recovery, as well as characterizing the symptoms which may affect operational performance immediately after TBI.

2.0 METHODS

2.1 Study Sample

The Expeditionary Medical Encounter Database (EMED, formerly the Navy and Marine Corps Combat Trauma Registry) was queried for all personnel injured during Operation Iraqi Freedom who completed a post-deployment health assessment (PDHA). This study was approved through the Institutional Review Board at Naval Health Research Center (NHRC), San Diego, CA.

The EMED is a deployment health database maintained by NHRC and consists of documented clinical encounters of deployed military personnel.[19] Clinical EMED records are completed by medical providers stationed at forward-deployed Navy and Marine Corps military treatment facilities (e.g. facilities located in Iraq to treat Operation Iraqi Freedom casualties). Unique aspects of the EMED include detailed information regarding the injury incident, which is collected at or near the point of occurrence, as well as the inclusion of persons with mild injuries who are subsequently returned to duty. Clinical records are provided to NHRC and professional coders review the records and assign medical codes using the Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), and International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM).[20-22]

The PDHA is a screening questionnaire developed by the Department of Defense to identify personnel in need of medical referral for a variety of health reasons.[23] The PDHA is given at the end of each deployment and has been used in previous research to identify population-level, mental health screening rates.[24]

Eligible personnel for the present study were service members who sustained a mild to moderate injury during Operation Iraqi Freedom between 2004 and 2008, and who completed a PDHA upon return from deployment. The sample was restricted to personnel who completed the PDHA within one year of their injury date. The final sample consisted of 3640 injured personnel (856 personnel with TBI and 2784 with non-head injury).

2.2 Measures

2.2.1 Demographic Variables

Age and military rank were abstracted from the EMED clinical record. Age was analyzed as a continuous variable and rank was categorized into enlisted and officer. Branch of service and gender were identified from administrative records, and branch of service was categorized into Army, Marines, and other (i.e. Navy and Air Force).

2.2.2 Injury Groups

Presence of TBI was identified from the EMED clinical records and was indicated by one of the following ICD-9 codes: 800-801, 803-804, 850-854. The non-head injury comparison group consisted of any injury where the head region was not specifically indicated in AIS coding.

2.2.3 Injury-Specific Variables

Type of injury was categorized as battle injury as a result of hostile action, or nonbattle, defined an injury resulting from nonhostile action. Injury type and presence/absence of blast mechanism was utilized to define injury mechanism as ‘battle, blast’, ‘battle, non-blast’, and ‘non-battle’. For multivariate analysis the variable was dichotomized into blast and non-blast. Injury severity was coded using the ISS, which ranged from 1 to 8 (mild to moderate injuries).

2.2.4 Combat Exposure

In order to assess combat exposure, the PDHA asks service members if they were: 1) exposed to dead bodies, 2) discharged their weapon, or 3) had a perceived threat to life. The specific questions are shown in Table 1. These three questions were used to create a dichotomous variable of ‘light combat exposure’ (i.e. those endorsing 0-1 of the combat exposure questions) and ‘moderate-high combat exposure’ (i.e. those endorsing 2-3 of the combat exposure questions).

2.2.5 PTSD

The PDHA also contains a validated PTSD screening instrument shown in Table 1. The 4-item PTSD screening instrument is based on the Primary Care PTSD screen and was recently validated against the 17-item PTSD checklist.[25,26] Endorsing any 3 of the 4 symptoms indicates a positive screen for PTSD.

Table 1: Posttraumatic stress disorder and combat experience questions, post deployment health assessments

Posttraumatic Stress	Combat Experience
Have you ever had any experience that was so frightening, horrible, or upsetting that, in the past month, you…	Did you see anyone wounded, killed or dead during this deployment? (yes/no)
Have had any nightmares about it or thought about it when you did not want to? (yes/no)	Were you engaged in direct combat where you discharged your weapon? (yes/no)
Tried hard not to think about it or went out of your way to avoid situations that remind you of it? (yes/no)	During this deployment, did you ever feel that you were in great danger of being killed? (yes/no)
Were constantly on guard, watchful, or easily startled? (yes/no)	
Felt numb or detached from others, activities, or your surroundings? (yes/no)	

2.2.6 PCS Symptoms

On the PDHA, the service member is asked if they currently have a health concern or condition they feel is related to their deployment. Current complaints of seven common PCS symptoms--headache, memory problems, still feeling tired after sleeping (i.e. sleep problems), back pain, joint pain, muscle pain and tinnitus--were abstracted from the PDHA.

2.2.7 Time to PDHA

Response time to the PDHA was calculated by subtracting the date of PDHA from the date of injury. Time was further categorized into the following post-injury time periods: 1-90, 91-180, and 180-365 days.

2.3 Data Analysis

All statistical analyses were performed using SAS version 9.2 (Cary, NC). Demographics, injury-specific information, and PDHA responses were described for the study sample by TBI status and compared utilizing chi-square and Wilcoxon tests for categorical and continuous variables, respectively. Rates of PCS symptoms were compared across TBI and non-head injury groups, and by post-injury time period using chi-square testing. A separate multivariate logistic regression model was utilized for each of the seven PCS symptoms to assess the independent effects of TBI at each time period after adjusting for age, combat

exposure, injury severity, injury mechanism, and PTSD. A separate analysis was conducted comparing crude and adjusted mean number of PCS symptoms for each of the time periods by TBI status using t-tests and least squares means.

3.0 RESULTS

Characteristics of the study population are outlined in Table 2. Compared to those with non-head injuries, those with TBI were more likely to be Marines (70.6% vs. 64.1%, p-value < 0.001), primarily enlisted (97.1% vs. 93.0%, p-value < 0.001), and predominantly male (99.0% vs. 91.0%, p-value < 0.001). The injury mechanism for TBI was most frequently battle, blast (87.2%) compared with non-battle for non-head injuries (56.2%). Non-battle TBI resulted primarily from motor vehicle accidents and falls. Those with TBI sustained more severe injuries overall (median ISS 2 vs. 1, p-value < 0.001). Time from injury to PDHA response differed significantly by TBI status (p-value = 0.002). Compared to non-head injuries, those with TBI were significantly more likely to report moderate-high levels of combat exposure (82.9% vs. 57.9%, p-value < 0.001) and screen positive for PTSD (24.1% vs. 13.3%, p-value < 0.001).

Table 2: Descriptive characteristics for sample of TBI and non-head injuries, Operation Iraqi Freedom, 2004-2008 (n = 3640).

Characteristics	TBI (n = 856)		Non-Head Injury (n = 2784)		P
Demographic					
Median age (range)*	22.0	(18-52)	23	(18-59)	<0.001
Branch of service, no. (%)					<0.001
Marines	604	(70.6)	1785	(64.1)	
Army	198	(23.1)	662	(23.8)	
Other	54	(6.3)	337	(12.1)	
Rank†					<0.001
Enlisted	831	(97.1)	2582	(93.0)	
Officer	25	(2.9)	195	(7.0)	
Male, no (%)	847	(99.0)	2532	(91.0)	<0.001
Injury-specific					
Median ISS (range)	2	(1-8)	1	(1-8)	<0.001
Mechanism, no. (%)					<0.001
Non-battle	97	(11.3)	1564	(56.2)	
Battle, blast	747	(87.2)	1044	(37.5)	
Battle, non-blast	12	(1.4)	176	(6.3)	
PDHA					
Time to response, no. (%)					0.002
1-90 days	386	(45.1)	1332	(47.8)	
91-180 days	382	(44.6)	1074	(38.6)	
181-365 days	88	(10.3)	378	(13.6)	
Combat exposure¶					<0.001
Light	146	(17.1)	1169	(42.1)	
Moderate-high	709	(82.9)	1611	(57.9)	
PTSD screen +, no. (%)¶	206	(24.1)	370	(13.3)	<0.001

* missing data n = 3
† missing data n = 7
¶ missing data n = 5

Table 3 shows the breakdown of PCS symptoms for each time period following TBI and non-head injury. Headache was the most commonly reported symptom by the TBI group within the first 90 days after injury. In all other time periods and in both groups, back pain was the most frequently reported symptom. In the first 90 days post-injury, rates of all symptoms with the exception of joint pain were significantly higher

among the TBI group compared to the non-head injury group. In the 91-180 day post-injury period, only headache (17.3% vs. 7.0%, p-value < 0.001), memory problems (10.7% vs. 6.6%, p-value 0.009) and tinnitus (19.1% vs. 11.9%, p-value < 0.001) were significantly higher in the TBI than the non-head injury group. All seven health complaints were higher in TBI compared with non-head injuries at 181-365 days post-injury, but differences in sleep problems were not statistically significant (p-value = 0.087).

Table 3: Number and percentage of health complaints following TBI and non-head injuries by time since injury

Health Complaint	1-90 Days			91-180 Days			181-365 Days		
	TBI (n = 386)	Non-Head (n = 1332)	P	TBI (n = 382)	Non-Head (n = 1074)	P	TBI (n = 88)	Non-Head (n = 378)	P
Headache	115 (29.8)	106 (8.0)	<0.001	66 (17.3)	75 (7.0)	<0.001	19 (21.6)	45 (11.9)	0.017
Memory problems	56 (14.5)	60 (4.5)	<0.001	41 (10.7)	71 (6.6)	0.009	18 (20.5)	35 (9.3)	0.003
Sleep problems	68 (17.6)	161 (12.1)	0.005	64 (16.8)	144 (13.4)	0.109	21 (23.9)	61 (16.1)	0.087
Tinnitus	80 (20.7)	136 (10.2)	<0.001	73 (19.1)	128 (11.9)	<0.001	20 (22.7)	43 (11.4)	0.005
Back pain	96 (24.9)	202 (15.2)	<0.001	87 (22.8)	213 (19.8)	0.222	38 (43.2)	86 (22.8)	<0.001
Muscle pain	60 (15.5)	157 (11.8)	0.050	50 (13.1)	120 (11.2)	0.317	21 (23.9)	52 (13.8)	0.019
Joint pain	60 (15.5)	198 (14.9)	0.742	56 (14.7)	149 (13.9)	0.704	21 (23.9)	55 (14.6)	0.033

Results from multivariate logistic regression are shown in Table 4. Symptom reporting among TBI trended higher in the 1-90 day and 181-365 day period. After adjusting for age, injury severity, blast injury mechanism, combat exposure, and PTSD, TBI relative to non-head injury was associated with increased odds of headache (OR 4.81, 95% C.I. 3.27-7.07), memory problems (OR 2.74, 95% C.I. 1.69-4.44) and back pain (OR 1.82, 95% C.I. 1.29-2.57) in the first 90 days. In the 91-180 day post-injury period, only headache is significantly higher among those with TBI (OR 2.15, 95% C.I. 1.38-3.36). When examining the 181-365 day post-injury period, headache (OR 2.32, 95% C.I. 1.05-5.13), memory problems (OR 2.76, 95% C.I. 1.17-6.53), sleep problems (OR 2.22, 95% C.I. 1.04-4.71), and back pain (OR 2.68, 95% C.I. 1.41-5.08) were all higher in TBI compared to non-head injury group. Tinnitus was associated with blast mechanism at all time periods, but not with TBI. At all time periods PTSD conferred a significantly greater odds of nearly every PCS symptom.

Total number of PCS symptoms is compared across time periods in Table 5. For every time period, crude mean number of symptoms was significantly higher in the TBI group compared to the non-head injury group, with the greatest number of symptoms reported in the 181-365 day period for both TBI (mean symptoms 1.80, S.D. ± 2.01) and non-head injuries (mean symptoms 1.00, S.D. ± 1.49). After adjusting for age, injury severity, blast injury mechanism, combat exposure, and PTSD, mean number of PCS symptoms were no longer different for the TBI group (adjusted mean symptoms 1.30) and non-head injury group (adjusted mean symptoms 1.25) in the 91-180 day post-injury period (p-value = 0.631).

Table 4: Multivariate logistic regression models examining the association between TBI and post-deployment health complaints, 1-90 days, 91-180 days, and 181-365 days

Model/ Variable	Adjusted Odds Ratios (95% Confidence Intervals)						
	Headache	Memory Problems	Sleep Problems	Tinnitus	Back Pain	Muscle Pain	Joint Pain
1-90 days							
Age	1.03† (1.01-1.05)	1.04† (1.01-1.07)	1.03† (1.01-1.05)	1.03† (1.01-1.06)	1.03‡ (1.01-1.05)	1.02† (1.00-1.05)	1.05§ (1.03-1.07)
ISS	0.93 (0.84-1.05)	0.98 (0.85-1.13)	0.97 (0.87-1.08)	1.07 (0.96-1.19)	0.93 (0.85-1.03)	1.14† (1.03-1.26)	1.07 (0.97-1.18)
Moderate-high/ light combat	1.51† (1.01-2.28)	2.11† (1.16-3.84)	1.66‡ (1.14-2.43)	2.73§ (1.70-4.40)	1.45† (1.05-2.01)	1.93‡ (1.31-2.86)	1.33 (0.95-1.86)
Blast/non-blast	0.85 (0.57-1.27)	0.95 (0.57-1.59)	0.90 (0.63-1.30)	2.38§ (1.61-3.53)	0.85 (0.61-1.18)	0.98 (0.68-1.41)	0.85 (0.61-1.20)
PTSD	4.38§ (3.12-6.16)	5.12§ (3.37-7.79)	4.26§ (3.07-5.92)	2.89§ (2.08-4.02)	2.88§ (2.11-3.92)	3.00§ (2.14-4.20)	2.69§ (1.93-3.75)
TBI/non-head	4.81§ (3.27-7.07)	2.74§ (1.69-4.44)	1.24 (0.84-1.82)	1.11 (0.77-1.60)	1.82§ (1.29-2.57)	0.87 (0.59-1.29)	0.91 (0.62-1.34)
91-180 days							
Age	1.02 (0.99-1.05)	1.03 (1.00-1.06)	1.01 (0.99-1.04)	1.02 (0.99-1.05)	1.01 (0.99-1.03)	1.04‡ (1.01-1.06)	1.03‡ (1.01-1.06)
ISS	1.04 (0.91-1.18)	1.13 (0.98-1.30)	1.06 (0.94-1.19)	1.13† (1.01-1.27)	1.01 (0.91-1.12)	1.05 (0.92-1.19)	1.02 (0.90-1.14)
Moderate-high/ light combat	1.24 (0.72-2.12)	1.46 (0.78-2.75)	1.41 (0.94-2.11)	2.71§ (1.59-4.64)	1.74‡ (1.22-2.49)	1.70† (1.06-2.73)	1.85‡ (1.20-2.83)
Blast/non-blast	1.43 (0.89-2.29)	1.36 (0.81-2.27)	0.76 (0.53-1.10)	2.43§ (1.61-3.68)	1.21 (0.88-1.66)	1.01 (0.67-1.51)	1.06 (0.73-1.53)
PTSD	4.05§ (2.72-6.02)	5.12§ (3.33-7.87)	3.43§ (2.42-4.85)	2.35§ (1.66-3.32)	2.61§ (1.91-3.57)	3.44§ (2.38-4.97)	2.83§ (2.00-4.00)
TBI/non-head	2.15§ (1.38-3.36)	1.10 (0.66-1.83)	1.16 (0.78-1.74)	0.90 (0.61-1.32)	0.93 (0.66-1.31)	0.96 (0.62-1.50)	0.87 (0.58-1.31)
181-365 days							
Age	1.03 (0.99-1.06)	1.02 (0.98-1.06)	1.00 (0.97-1.03)	1.00 (0.96-1.04)	1.01 (0.98-1.04)	1.01 (0.98-1.05)	1.03 (1.00-1.06)
ISS	0.96 (0.76-1.21)	0.89 (0.68-1.17)	0.87 (0.68-1.10)	1.12 (0.90-1.38)	0.97 (0.80-1.17)	1.00 (0.80-1.26)	1.18 (0.96-1.44)
Moderate-high/ light combat	1.43 (0.74-2.74)	1.92 (0.89-4.18)	1.33 (0.74-2.39)	1.90 (0.90-4.00)	1.62 (0.97-2.69)	1.70 (0.88-3.29)	1.18 (0.64-2.18)
Blast/non-blast	0.70 (0.36-1.39)	0.71 (0.33-1.51)	0.61 (0.33-1.15)	2.27† (1.15-4.51)	0.72 (0.42-1.23)	0.90 (0.47-1.72)	0.97 (0.52-1.82)
PTSD	2.16† (1.06-4.40)	4.71§ (2.35-9.44)	3.01§ (1.58-5.74)	1.78 (0.87-3.63)	2.59‡ (1.41-4.74)	4.77§ (2.52-9.04)	2.79‡ (1.44-5.42)
TBI/non-head	2.32† (1.05-5.13)	2.76† (1.17-6.53)	2.22† (1.04-4.71)	1.07 (0.51-2.25)	2.68‡ (1.41-5.08)	1.57 (0.73-3.37)	1.24 (0.60-2.58)

† p-value 0.01-0.05
‡ p-value 0.001-0.009
§ p-value <0.001

Table 5. Overall and adjusted mean number of symptoms following TBI and non-head injury by time since injury

Mean ± S.D.	1-90 Days			91-180 Days			181-365 Days		
	TBI (n = 386)	Non-Head (n = 1332)	P	TBI (n = 382)	Non-Head (n = 1074)	P	TBI (n = 88)	Non-Head (n = 378)	P
Overall	1.39 ± 1.80	0.77 ± 1.32	<0.001	1.14 ± 1.68	0.84 ± 1.43	0.002	1.80 ± 2.01	1.00 ± 1.49	<0.001
Adjusted*	1.61	1.21	<0.001	1.30	1.25	0.631	2.14	1.49	0.004

*Adjusted for age, ISS, combat exposure, blast mechanism, and PTSD.

4.0 DISCUSSION

Traumatic brain injury is an emerging wound among U.S. military personnel.[1-4] Although previous studies have examined sequelae of blast-related TBI, none have attempted to estimate the trajectory of symptoms over time. The present analysis is the first to examine PCS symptoms as a function of time since injury. Results suggest an initial peak in symptom reporting during the first 90 days post-injury, followed by a reduction in reporting, then a second peak at the 181-365 day post-injury period. These findings have implications for management of TBI in theatre and should be supplemented with further analyses involving repeated measures of common PCS symptoms in personnel with and without TBI.

The present study found that TBI, relative to non-head injury, was associated with headache, memory, and back pain complaints in the initial 90 days post-injury. This is consistent with civilian literature on TBI that shows significant rates of adverse symptom reporting in the acute phase of injury.[9-11] This may have operational implications, as memory problems and cognitive deficits may affect performance of certain job duties. Additionally, back pain is a common symptom during deployment, further evidenced by the high rates among non-head injuries. Body armor has been implicated in musculoskeletal complaints including back pain,[27, 28] and TBI may exacerbate conditions related to carriage of heavy combat loads. Rehabilitation efforts at or near the point of injury should be considered to ameliorate these initial symptoms in order to minimize any effects on operational performance.

Though the reduction in symptom reporting at the 91-180 day post-injury period was not altogether surprising given typical trends in TBI recovery, the heightened health complaints at the 181-365 day period was unexpected. It appears that the results do not follow the typical TBI symptom recovery pattern observed in civilian studies.[9-11] The appearance of this quadratic trend may be explained by multiple hypotheses. It is likely that those who are returned to duty following a TBI, and who finish their deployment as scheduled, are at risk for further exposure to blasts. Naturally this risk would increase as a function of time remaining on deployment. Subsequent blast exposures may not be well documented in clinical records, or may appear so mild that the service member does not seek care. Cumulative effects of repeated TBI have been documented in the civilian literature,[29-31] though further research is needed to characterize this problem among military personnel. Alternatively, Lishman proposed that barriers to recovery may allow the effects of TBI to persist.[32,33] Though Lishman was referring primarily to mental health conditions that cause PCS symptoms to persist, it is possible that remaining a stressful, austere environment, such as a combat zone, can hinder full recovery from TBI. Finally, the effects may be the result of the small sample size of TBI (there only 88 persons in the 181-365 day period compared to > 300 in the earlier two time periods). As such, future research should examine this association in a larger sample.

There were secondary findings of interest. Headache was the only health complaint consistently higher among TBI at all time periods, which is consistent with previous reports among military veterans.[14,34] Although tinnitus has commonly been reported as a sequela of TBI,[35] multivariate analysis from the present study does not support this. Blast mechanism, however, was significantly associated with tinnitus,

suggesting that tinnitus may be more a product of noise-induced trauma from the blast rather than the organic brain injury. We also found that PTSD was strongly associated with nearly all PCS symptoms at all time periods. Although recent research has focused on the emerging problem of combat-related TBI, it should be noted that PTSD remains a major source of morbidity among military personnel,[36] and that PTSD itself is associated with an array of negative health consequences among military veterans, including physical and behavioural problems.[37-38] It is imperative that future research on TBI continues to address the overlap of PCS symptoms with PTSD.

The current study had several strengths. Because of the unique characteristics of the EMED data (i.e., accurate injury dates) as well as the ability to link this data with self reported health information on the PDHA, the trajectory of symptoms in combat-related TBI could be approximated. In addition, the use of provider-diagnosed TBI corrects for many of the inherent limitations of self-reported TBI measures, such as recall bias.[16] The use of point of injury clinical records also allowed for abstraction of specific injury incident information, including details about mechanism and severity of injury.

This study also has limitations that warrant mention. Although the study design attempted to examine symptom trajectory over time, this is based on an arbitrary date as to when the service member responds to a PDHA relative to their injury date; i.e. administration of the PDHA is based on deployment end date, which is not necessarily associated with injury. Ideally, data on PCS symptoms following TBI should be collected in a repeated measures fashion, so individual recovery from symptoms can be estimated. To accomplish this, however, collection of data in a combat zone would likely be required. Also, the nature of the EMED data creates an oversampling of Marines, as data is collected from Navy and Marine Corps medical facilities only; Army personnel may be under-represented and the results may not generalize to all military personnel.

The present study represents the first attempt to identify a trajectory of PCS symptoms following combat-related TBI. Due to the austere environment where these injuries occur, such studies are problematic and logistically difficult. The novel use of existing data provides valuable information, though these findings need to be replicated in focused studies incorporating repeated measures of in-theatre combat personnel. The recovery environment for combat-related TBI, as well as the potential effects of repeated blast exposures, requires further investigation. While blast weaponry persists as a primary mode of current warfare, acute and persistent effects of TBI need to be further defined.

5.0 REFERENCES

[1] Okie S. Traumatic brain injury in the war zone. N Engl J Med. 2005;352(20):2043-2047.

[2] Warden D. Military TBI during the Iraq and Afghanistan wars. J Head Trauma Rehabil. 2006;21(5):398-402.

[3] Martin EM, Lu WC, Helmick K, French L, Warden DL. Traumatic brain injuries sustained in the Afghanistan and Iraq wars. *American Journal of Nursing*. 2008;108(4):40-47.

[4] Zeitzer MB, Brooks JM. In the line of fire—traumatic brain injury among Iraq War veterans. *AAOHN J*. 2008;56(8)347-353.

[5] Institute of Medicine. *Gulf War and Health: Long-Term Consequences of Traumatic Brain Injury*. Vol 7. Washington, DC: National Academies Press; 2009.

[6] Iverson GL. Outcome from mild traumatic brain injury. Current Opinion in Psychiatry. 2005;18:301-17.

[7] Alves W, Macciocchi SN, Barth JT. Postconcussive symptoms after uncomplicated mild head injury. J Head Trauma Rehabil. 1993;8(3):48-59.

[8] Howe LS. Giving context to post-deployment post-concussive-like symptoms: blast-related potential mild traumatic brain injury and comorbidities. The Clinical Neuropsychologist. 2009;23:1315-37.

[9] Carroll LJ, Cassidy D, Peloso PM, et al. Prognosis for mild traumatic brain injury: results of the WHO collaborating centre task force on mild traumatic brain injury. J Rehabil Med. 2004;Suppl. 43:84-105.

[10] McCrea M, Iverson GL, McAllister TW, et al. An integrated review of recovery after mild traumatic brain injury (MTBI): Implications for clinical management. The Clinical Neuropsychologist. 2009;23:1368-90.

[11] McCrea MA. Mild traumatic brain injury and postconcussion syndrome. New York, New York: Oxford University Press; 2008.

[12] MacGregor, AJ, Shaffer RA, Dougherty AL, et al. Psychological correlates of battle and nonbattle injury among Operation Iraqi Freedom veterans. Military Medicine. 2009;3:224-230.

[13] Seal KH, Bertenthal D, Miner CR, Sen S, Marmar C. Bringing the war back home: mental health disorders among 103,788 US veterans returning from Iraq and Afghanistan seen at Department of Veterans Affairs facilities. Arch Intern Med 2007;167:476-82.

[14] Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild traumatic brain injury in U.S. soldiers returning from Iraq. NEJM. 2008;358(5):453-63.

[15] Pietrzak RH, Johnson DC, Goldstein MB, Malley JC, Southwick SM. Posttraumatic stress disorder mediates the relationship between mild traumatic brain injury and health and psychosocial functioning in veterans of Operations Enduring Freedom and Iraqi Freedom. J Nerv Ment Dis. 2009;197(10):748-53.21.

[16] Iverson GL. Clinical and methodological challenges with assessing mild traumatic brain injury in the military. J Head Trauma Rehabil. 2010;25(5):313-9.

[17] Ruff RM, Iverson GL, Barth JT, Bush SS, Broshek DK. Recommendations for diagnosing a mild traumatic brain injury: a National Academy of Neuropsychology education paper. Archives of Clinical Neuropsychology. 2009;24:3-10.

[18] Bryant RA. Disentangling mild traumatic brain injury and stress reactions. NEJM. 2008;358(5):525-7.

[19] Galarneau MR, Hancock WC, Konoske P, et al: The Navy-Marine Corps Combat Trauma Registry. Mil Med 2006; 171(8): 691-7.

[20] Gennarelli T, Wodzon E. The Abbreviated Injury Scale – 2005. Des Plaines, IL: Association for the Advancement of Automotive Medicine 2005.

[21] Baker SP, O'Neill B, Haddon W, Long WB: The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974; 14: 187-96.

[22] Commission on Professional Hospital Activities. International Classification of Diseases, 9th Revision, Clinical Modification. Ann Arbor, MI: Edwards Brothers; 1977.

[23] Post–deployment health assessment form (DD Form 2796). April 2003. http://www.pdhealth.mil/dcs/DD_form_2796.asp. Accessed September 19, 2010.

[24] Hoge CW, Auchterlonie JL, Milliken CS. Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. JAMA. 2006;295(9):1023-32.

[25] Prins A, Quimette P, Kimerling R, et al: The primary care PTSD screen (PC-PTSD): development and operating characteristics. Primary Care Psychia. 2004; 9: 9-14.

[26] Bliese PD, Wright KM, Adler AB, Cabrera O, Castro CA, Hoge CW. Validating the primary care posttraumatic stress disorder screen and the posttraumatic stress disorder checklist with soldiers returning from combat. J Consult Clin Psychol. 2008;76(2):272-81.

[27] Konitzer LN, Fargo MV, Brininger TL, Lim Reed M. Association between back, neck, and upper extremity musculoskeletal pain and the individual body armor. J Hand Ther. 2008;21(2):143-8.

[28] Knapik JJ, Reynolds KL, Harman E. Soldier load carriage: historical, physiological, biomechanical, and medical aspects. Military Medicine. 2004;169(1):45-56.

[29] Guskiewicz KM, Marshall SW, Bailes J, McCrea M, Cantu RC, Randolph C, Jordan BD: Association between recurrent concussion and late-life cognitive impairment in retired professional football players. Neurosurgery. 2005;57:719–726.

[30] Thornton AE, Cox DN, Whitfield K, Fouladi RT. Cumulative concussion exposure in rugby players: Neurocognitive and symptomatic outcomes. J Clin Exp Neuropsychol. 2008;30:398–409.

[31] Gronwall D, Wrightson P. Cumulative effect of concussion. Lancet. 1975;2:995–997.

[32] Crowe SF. The behavioural and emotional complications of traumatic brain injury. New York, New York: Taylor and Francis Group, LLC; 2008.

[33] Lishman WA. Physiogenesis and psychogenesis in the 'post-concussional syndrome'. British Journal of Psychiatry. 1988;153:460-9.

[34] Theeler BJ, Erickson JC. Mild head trauma and chronic headaches in returning U.S. soldiers. Headache. 2009;49:529-34.

[35] Lew HL, Jerger JF, Guillory SB, Henry JA. Auditory dysfunction in traumatic brain injury. JRRD. 2007;44:921-928.

[36] Hoge CW, Castro CA, Messer SC, McGurk D, Cotting DI, Koffman RL. Combat duty in Iraq and Afghanistan, mental health problems, and barriers to care. NEJM. 2004;351(1)13-22.

[37] O'Toole BI, Catts SV. Trauma, PTSD, and physical health: an epidemiological study of Australian Vietnam veterans. Journal of Psychosomatic Research. 2008;64(1):33-40.

[38] Highfill-McRoy RM, Larson GE, Booth-Kewley S, Garland CF. Psychiatric diagnoses and punishment for misconduct: the effects of PTSD in combat-deployed Marines. BMC Psychiatry. 2010;10(1):88.